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Physics as a Way of Thinking*

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There is always before us one supreme question. From what angle may we view the physical and social world so that it may be reasonably intelligible, so that we may feel a friendly relation to it and accept it as our home. The Buddhist finds his answer in a toleration for what he may neither understand nor alter. The Greeks like others under similar conditions asked this question and replied with a lucidity peculiar to themselves, "It is something like myself." In such an answer there is no attempt to rise above immediate human needs and satisfactions and to find universal relations which are independent of time and space. The physical scientist on the other hand must thrust aside all personal and social implications of the physical world and address himself to finding order and system among physical phenomena. Here it is proposed to look at some of the more essential characteristics of physical thinking, to trace the way in which they have developed and to suggest how this way of thinking may have validity in other fields of thought. Approached in this way, physics is considered not as a framework which determines our material environment but as a type of thinking which penetrates our intellectual atmosphere — not as a record of achievements and tendencies but as an indication of essential characteristics of the human mind in its attempt to build around itself an ordered and organized universe which will be an agreeable intellectual habitation.

To get an impression of primitive man's approach to the physical universe one can scarcely do better than to quote from G. Lowes Dickinson. "When we try to conceive of the state of mind of primitive man, the first thing that occurs to us is the

* Much which this paper contains, both in ideas and phraseology, I owe to Jeans, Planck, Eddington, and Dingle.

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bewilderment and terror he must have felt in the presence of the powers of nature. Naked, homeless, weaponless, he is at the mercy, every hour, of this immense and incalculable Something, so alien and hostile to himself. As fire it burns, as water it drowns, as tempest it hurries and destroys; benignant it may be at times, in warm sunshine and calm but the kindness is brief and treacherous. Anyhow, whatever its mood, it has to be met and dealt with. By its help or in the teeth of its resistance, each step in advance must be won. every hour, every minute it is there to be reckoned with." Here we have the background of an animistic interpretation of nature. This was the first and simplest way man found to make himself at home in the physical world. To do it he called forth all that was alien in the world and clothed it in human form, converted all the mysterious powers of nature into beings like himself only more powerful and thus ended by making the world of nature an expression or an enlargement of himself. Thus conceived, the physical world became familiar and somewhat comprehensible. Starting with this picture we may trace the history of physical science as the history of the human mind adjusting itself by an infinite series of steps to the physical world, assimilating here a bit and there a bit of material and ever trying to escape the apparent chaos which surrounds it.

The animistic period represented by the attitude of the early Greeks was followed by a long period ending about 1550 A. D. in which there was comparatively little advance in our knowledge of the physical universe. In this period dominated by Greek philosophy, the interpretation of nature was an achievement of pure thought unsupported by observation and experiment. Man was the center of the frame of reference to which all physical phenomena were referred. Since he seemed always to be actuated by purposes, it was assumed that the universe must also be for a purpose. Everything existed for man's purpose. The sun to give him light and heat; the rain to insure him food and proper living conditions; the plants and animals for his comfort or pleasure. In brief, the physical world was a setting for man's destiny. Referred to this frame of reference the interpretation of physical phenomena became an unverified achievement of the human mind. This egocentric and teleological point of view was very satisfying and persistent. It made man the center of the universe, the measure of its meaning and the observation post from which all events must be viewed. The tenacity with which man clung to this point of view is evident from the bitterness of the controversy which arose when Copernicus proposed to use the sun instead of the earth as the center of the solar system. At that time it seemed to man that if he, himself, were not really the center of the universe, then at least this planet on which he finds himself must be the most significant spot in an unexplored universe and must be used as the center from which all observations are made and all results are evaluated. Now nothing of this point of view is left in modern physics. To a greater or less degree it persists in the biological and social sciences. But just as physics had to free itself from a teleological point of view so also must these other sciences free themselves from modes of thought or types of reasoning which involve emotion, design, or purpose.

A second error in the Greek metaphysical approach to nature arose from the fact it assumed perfection for the universe and on the basis of inadequate observations tried to force nature to fit into this hypothesis. Objectionable facts were overlooked and principles supported when observations were contrary to them. Such an hypothesis of congealed and crystallized perfection removes the universe from all change and allows us to proceed as if we were dealing with a fixed and unchangeable group of physical phenomena for which a final interpretation is once and for all time possible. Such an approach, even when supplemented by controlled experiments and observations introduces the concept of an absolute and fixed mode of thought in which it is assumed that man can penetrate the world of sense-perceptions and reach a world of reality which has some kind of existence independent of himself — a real and absolute world to which we may approach more and more closely with ever increasing accuracy The contrast between Euclidean geometry and Riemann geometry serves as an illustration. Euclidean geometry emanates from postulates accepted as self evident and leads to propositions supposed to be factually true about physical space. Riemann geometry starts from another set of postulates and leads to another description of space. If we accept the hypothesis that an absolute interpretation of nature is possible, we may ask which of these geometries is correct. In reality the question has no meaning. The only question that can be rationally asked is, which of these geometries is the more helpful in the description and correlation of physical phenomena. Euclidean geometry is and must remain the most convenient but it is neither more nor less correct than Riemann geometry. Even after Galileo and Newton had shown that reasoning about physical phenomena must begin and end with observation and experiment, the attempt to deduce physical phenomena from fixed postulates persisted and it has required the recent developments in the theory of relativity, in subatomic physics and quantum mechanics to make us fully realize the extent to which our thinking has been colored and made invalid by fallacious underlying postulates for which there were insufficient reasons in nature. Without a clear appreciation of this fact the physical sciences would never have realized that new physical propositions cannot be arrived at by any form of syllogism without verification by observation and experiment and that habit, custom, and tradition have played and are playing a very important part in comparison with intelligence in the accepted views of the universe.

This failure to press the physical universe into a preconceived pattern designed for a definite purpose or emanating from accepted postulates, has wide significance in other fields of thought. In educational discussions we frequently set out from a set of postulates, proceed as if new truth can be deduced from definitions or general laws from a study of phenomena not originally included in the formulation of the law The progress of the physical sciences very clearly suggests that any attempt to formulate a preconceived scheme of education good for a hundred years is doomed to complete failure. New forces will be in operation, new situations must be met and new adjustments made. We cannot get along with an educational philosophy which emanates from the idea that a knowledge of the past and an assimilation of the culture of the past are sufficient. We must know vastly more than the fact that events happened in the past in some kind of sequence, whether this is a sequence in time or in space. Writing with a similar thought in mind Professor Cook says that courts must not be content to deduce conclusions from fixed principles or to derive a fundamental principle from the constitution and to apply it some new form of legislation. They must be able to abstract a new rule or modify an old rule, enrich new concepts or abandon old ones so that social justice and economic well being may be conserved. This newer and more scientific method is seen in a recent decision handed down by the Supreme Court of the United States in which it is affirmed that "The Constitution does not secure to any one liberty to conduct his own business in such a fashion as to inflict injury on the public at large or upon any substantial group of the people. Neither property rights nor contracts rights are absolute, for government cannot exist if the citizen may at will use his property to the detriment of his fellows or exercise his freedom of contract to their harm."

After experiment and observation have supplied the necessary data on which to build, the first essential of physical reasoning is to abstract from this data concepts which can be used as invariants for the description of the phenomena under consideration. One of the most important concepts thus abstracted from nature is the concept of time. Primitive man must have noticed that events did not occur simultaneously. He must have observed the rising and the setting sun and the changes of the seasons and acquired some experience in noting longer or shorter intervals of time. There thus developed through the ages an experience which we call time. Newton thought of time as an absolute entity but we only know of the stream of time and we can only measure time intervals, that is, determine whether one time interval is long or short as compared to a fixed interval. In much the same way sense perceptions gave us the concept of space. Newton thought of absolute space as well as absolute time, but after all, we only know of space relations or the relation of objects to each other in space. Here we have abstracted from nature two concepts — time and space. Newton thought of them as absolute and independent. Einstein shows that they are relative and dependent on each other.

This process of abstracting invariant concepts from complex physical phenomena is a difficult undertaking. It begins by removing from the observations all the qualities except the most essential characteristics which are common to them all. In dealing with gross matter the physicist finds the concept of mass valuable. To arrive at this concept he strips from matter its other characteristics, such as color, hardness, shape, or odor and saves the one essential characteristic, the amount of matter in the body The real difficulty in getting on in physics is the difficulty of stripping from new facts or concepts a mass of irrelevant details which at first seems indispensable and then guessing which of the essential facts will furnish a key for understanding physical phenomena.

To make somewhat more concrete this procedure, consider two important physical concepts, particles whether atoms or electrons and waves. Very early in the development of physical science our sense perceptions gave us the concept of particles, grains of sand or drops of water But as smaller and smaller scale phenomena demanded interpretation, for example the diffusion of gases or the law of multiple proportions, it was necessary to reduce the size of the unit of matter to smaller and smaller dimensions, ending for sometime with the hypothetical atoms of Dalton which were not only unobserved but unobservable. The properties to be assigned to these atoms were those necessary to make them capable of correlating the physical phenomena under consideration. Initially it was necessary to suppose that they were small, hard, perfectly elastic spheres, moving in absolute space and time and obeying laws which had been found useful instruments of description for large scale phenomena. These entities which we call atoms have no physical reality in excess of that attributed to them for the explicit purpose of describing phenomena. When new and ampler data were revealed by experiment, additional and unexpected properties were assigned to these atoms. They were found to be made up of other particles, some charged with positive and some with negative electricity Instead of being solid spheres they had to be regarded as miniature solar systems with central suns and small negatively charged planets. The important point is that whatever properties were assigned to these atoms and their constituents were just those properties which made the atoms effective instruments of description for the physical phenomena under consideration.

Sense perceptions gave the physicist another concept which has proved extremely valuable as a language in terms of which to describe physical phenomena. Suppose you drop a pebble into the surface of a pool of water. You find what the physicist calls a system of waves going out from the center of this disturbance. If you observe the characteristics of this disturbance you find a certain set of properties which can be abstracted, for example the wave length, the displacement, the frequency, and the velocity These universal characteristics we call the characteristics of wave motion and we find them useful symbols in terms of which to describe a great variety of phenomena. In the hands of Young and Fresnel they gave an interpretation of the interference and diffraction of light. In the hands of Maxwell they offer a basis for an understanding of electromagnetic waves and paved the way for wireless telegraphy and telephony

But these two concepts did not prove uniquely supreme in their original fields of usefulness. When it began to appear that the phenomena of light could be successfully interpreted as a wave motion new facts were discovered which could not be interpreted in terms of wave motions, and it was necessary to reintroduce into radiation phenomena ideas associated with particles and to build up a supplementary description of radiation phenomena in the language of particles. Similarly when it appeared that the language of the particle theory was about to prove adequate for a description of small scale phenomena in the field of subatomic physics, it was discovered that it was necessary to use the language of waves to describe some of the characteristics of electrons and protons. This important turn in physical methods very forcibly reminded the physicist of the limitations of his method, emphasizing the fact that we are dealing with concepts abstracted from gross phenomena and then using these concepts for the description and correlation of phenomena which may be beyond the range of sense perceptions. There is now no more reason for regarding an electron as entirely a particle than there is for describing radiation entirely in terms of waves. The result is that both the concept of waves and the concept of particles are needed to describe electrons and both the concept of particles and of waves are needed to describe radiation.

These simpler and more concrete types of abstractions and invariants which are immediately abstracted from physical phenomena have proved inadequate to meet the full needs of modern physics and it has been found necessary to supplement them by hypothetical abstractions which are of necessity beyond observation. The whole structure of modern physics is built on this kind of abstractions. The spinning electron is a hypothetical abstraction introduced to correlate certain spectroscopic phenomena, but there is no thought that direct experiment will verify or disprove its hypothetical spin. Such abstractions are essentially conceptical in their nature without any properties which subject them to experimental laws. They can be endowed with any characteristics which enable them to correlate phenomena. They are neither observable nor real in the sense that ordinary existences are observable or real. They are very different from potential experiences. They are a kind of mental edifice into which has been introduced any rational ideas which are helpful in the correlation of physical phenomena. The sole criterion is that they must accommodate experience and interrelate phenomena.

After fundamental entities or invariants have been abstracted, they must be formulated into mathematical laws or principles. In this way Newton formulated principles which were inseparably wedded to the phenomena they described. Whatever could not be deduced from the phenomena had no place in his experimental philosophy Every observer before Newton must have inquired about the conditions which determine the path of a flying arrow or a falling stone. It took the genius of Newton to see the simple rule which unites and interprets these phenomena. To get the rule he abstracted from the phenomena certain unchanging entities in terms of which the phenomena could be described and then put these entities together in a simple mathematical formulation, thus abstracting the rule from the phenomena themselves. Having abstracted time and space as fundamental and apparently independent entities, Newton set up an absolute frame of reference for physical phenomena which was consistent with all experience up to Newton's time, but when high speeds with which Newton had no occasion to deal were observed, it was necessary to abandon the concepts of absolute time and space and replace them by a new abstraction — the concept of time-space as a single entity, remembering that the way in which they are to be united depends on experiment. This procedure amounts to regarding time as a fourth dimension with all the essential properties of a distance. The result is as if we had formed an abstract medium which has four dimensions, length, breadth, thickness, and time instead of two media — time with one dimension and space with three dimensions. Now absolute time and space were abstractions from observations. In just the same way time-space is an abstraction from observation. The latter is to be preferred over the former because it correlates a larger range of observations and this is the sole test of its correctness or incorrectness. Thus Einstein extends the method of Newton into regions about which Newton could have no information, but he did vastly more. He showed that an absolute frame of reference could have no meaning, that two persons can logically differ as to the simultaneity of two events — one observing that the events occur at the same time and the other observing with equal confidence that these same events occur at different times. We were thus forced to abandon those fundamental concepts of both time and space which had become the very cornerstones of our interpretation of nature. At the same time we abandoned our belief in any real meaning of absolute length in the sense that one set of measures could be characterized as right and another set as wrong. There are an infinite number that may be considered right if suitable frames of references have been chosen. With the abandonment of our ideas of absolute time and space goes also the abandonment of our ideas of the absolute in the physical universe. There may be an infinite number of interpretations of nature depending on the frames of reference to which the physical phenomena have been referred. The physicist tries to express the laws of nature so that no matter what frame of reference the data are referred to, we always get the same results. This means that the laws must be invariant under any transformation from one system of coordinates to another This is the severest test of correctness and universality In each case the initial conditions must be specified as well as the characteristics of the frames of reference. The final picture may seem to be different to different observers but the description of the facts may be accurate in each case. To one observer the path of a planet may appear to be a circle;

to another it may appear to be an ellipse. The question of correctness or incorrectness is not raised. The accuracy and the sufficiency of the description is all that we can insist upon. The equations describing these physical phenomena may have different forms according to the frame of reference to which they are referred. The answer is the same but the form of expression is different. Hence a physicist can tell from the form of the equations whether Maxwell's equations are referred to fixed or moving system of axes or to a Newtonian or an Einstein frame of reference.

So Newtonian mechanics is extended by relativistic mechanics and the concept of the absolute is replaced by the concept of the relative. The point of view of Newton proves to be too narrow but besides clarifying most large scale phenomena it led to the belief or faith that there is an order in nature, that Venus will follow the same orbit whether or not we are observing her, that the spectrum of hydrogen is the same on the sun as in the laboratory Furthermore this new method established the right of the human mind to deal directly with physical phenomena without the acceptance of external authority. The authority of tradition was replaced by the authority of experiment and observation.

With these developments physicists ceased to be interested in a possible world of reality which might lie behind the world of sense perceptions. Such an abstraction perhaps necessary to satisfy some modes of thought has not proved helpful in the clarification of physical phenomena. On the other hand, the physical world is not considered as something apart from the physicist who studies it,—something to be explored from a distance, somewhat absolute both in time and space, something which had been before man appeared and will be the same when the last man disappears. This new attitude may be stated in an abridged quotation from Jeans, "The ancient Hebrew, the analogue of the nineteenth century physicist, saw the rainbow as an objective structure set in the heavens for all men to behold the token of a covenant between God and man and as objective as the signature on a check. We know that the objective rainbow is an illusion. Raindrops break the sunlight up into rays of many colors and the colored rays which enter any man's eyes from the rainbow form the rainbow he sees but the rainbow which enters one man's eyes can never enter those of a second man. No two men can see the same rainbow. Each man's rainbow is a selection of his own eyes, a subjective selection from an objective reality which is not a rainbow at all." It is much the same in all physical phenomena. We are less concerned with the absolute and more with the relative. We have learned that all we can ever hope to know is the relation of physical phenomena to each other. We have also learned to be liberal minded, to consider all sides of a question, to suspend judgments and be prepared for a reversal of opinions with the introduction of new experimental evidence. There are no necessary laws. One pattern or design is not to be preferred over another, except as one is more inclusive or more precise than the other. We realize now that we are viewing the world through human spectacles and that we must recognize the distortion which they may introduce. Much of the simplicity, intimacy and certainty of our earlier explanations were introduced by our way of looking at phenomena and are not really inherent in nature itself. We further realize that man is a creature in the process of making himself and that he must not tie himself down to what he knows and ignore what he does not know His divinations and guesses may be more important than his certainties. He must direct his attention to dealing with phenomena in terms of concepts abstracted from the phenomena themselves and he must be willing to refer these phenomena to any frame of reference which has the essential characteristics of convenience and simplicity

"The world of physics is then," as Planck says, "a deliberate hypothesis put forth by a finite mind in an attempt to reduce the facts of observation to a system based on certain physical principles such that known phenomena are necessary consequences of the system." The basic principles are chosen on experimental grounds. Whether they are true or false in the absolute sense is not a pertinent question. Their consequences must agree with nature. They are working hypotheses which are to be discarded whenever they cease to be effective or helpful. Progress means bringing new sets of observations with the system in a way to give a complete mathematical description of physical phenomena in terms of the fewest principles or entities, that is to find in a variety of physical phenomena essential relations from which future phenomena can be predicted. Physics is thus a result of our quest for order and harmony among physical phenomena. It is man's best attempt to think vigorously whatever permits of vigorous thinking. It is not fixed but is subject to change and evolution. Whatever comes out must go back to enrich the soil from which it came.

The successes which have followed this approach to nature and the possibilities which lie ahead are evident. Never before has our intellectual horizon been so extended as it has since these modes of thought began to be applied. In the direction of large scale phenomena we have arrived at almost limitless space populated by spiral nebulae, more or less uniformly distributed, through a sphere which is a million or more light years in radius. In the direction of small scale phenomena, we have determined the essential constituents of the atom and their arrangement with respect to each other and are now addressing ourselves to the more difficult problem of the nucleus, with increasing evidence of success. An unlimited number of problems still lie between these extremes, awaiting an attack by an extension of these methods. The possibilities are limited only by the imagination, experimental skill and intellectual ingenuity of man. Just as the Copernican theory assigned a different place to man in the universe, so also modern physics and astronomy are producing immense changes in man's outlook on the universe, revealing to him new types of thinking and adding new meaning to human life. The development of quantum mechanics has given a knowledge of the internal characteristics of the atom which is nearly as complete and self consistent as our knowledge of celestial mechanics. This development was only possible after the introduction of a new and strange form of physical analysis which gave a new meaning to physical explanation. The sublime order which is thus emerging from the former chaos, must be somewhat inherent in the world of sense perceptions. It can not be merely the working of man's mind.

Now this process of abstracting significant and universal characteristics from phenomena is not peculiar to the physical sciences but in them it has found its most perfect development. The biologists have abstracted such concepts as cells and genes and used them for the explanation of living organisms. Artists and musicians must avail themselves of this method of procedure and a great poet must have caught something from the situation which is to be universal and invariant through the ages. The economists are concerned with purchasing power but this is only an attempt to find a concept which is universal in its characteristics without asking what particular goods or services are involved. In psychology consciousness is an abstraction from mental behavior just as time and space are abstractions from sense perceptions. Justice is an abstraction from social relations for the description of social phenomena and one does not undertake to express it in terms of physical abstractions.

Social and economic laws just as physical laws must rest on direct observation and on a study of the actual structure and function of our modern social and economic life. They must correlate facts which actually exist—not those which are especially desired or fancied by some prejudiced observer. These laws must be expressed in terms of social concepts abstracted from the phenomena themselves. What the social scientist wants is not descriptions in terms of nebulous and ill-defined ideas. The political theorist can not get on with abstractions like the people, sovereignty, electorate, liberty, public welfare without a clarification of these concepts. He must know how human beings inter-act and these inter-actions must be described in terms of social, economic, and political abstractions, not in terms of physical or biological abstractions. Nor will it be enough to apply pre-existing concepts and terms to which fixed meanings have become attached. The excessive use of the indivisible atom speaks strongly against such a procedure. With each new advance in the theory of matter, this atom has been remoulded and enriched with new and important properties. In like manner it will be necessary for the social scientist to enrich his terms and concepts, to make them describe new relations and satisfy the ends for which they were created.

In dealing with social and economic data it will be found necessary to parallel another recent development in physics. The essence of this development is the attempt to discard from physics any material which is purely speculative and leads to conclusions which cannot be tested by experiment. The prediction of every physical theory must be capable of proof or disproof by an appeal to observation. This condition requires that every theory or explanation must rest primarily on observable entities. If the human mind is to find a way to think itself out of its social and economic difficulties it must more and more follow this example of the physical sciences and formulate its laws in terms of verifiable relations. When we have the same kind of analytical study of the social sciences that we have of the physical sciences we will find less indifference to the lessons they teach. Whatever indifference man has had to the past as a teacher he has been duly respectful of the message expressed in the chemical forces released in high explosives or the electrical forces manifested in lightning. If the conclusions of history were equally certain we might not need to consider the quotation attributed to Hegel. "We learn from history," said Hegel, "that we learn nothing from history" Such a statement means that we have not learned to abstract from social phenomena concepts in terms of which social phenomena can be described with certainty and future social phenomena predicted.

The progress of the physical sciences teaches us clearly that if we are to avoid a muddled state of mind we must recognize that we are not living in a fixed environment and that our habits of thought must continually adjust themselves to a changing world controlled largely by advances in scientific technology At the present rate of advance a given individual will be called upon to face more and more situations which have little parallel with the past. This is no world for a man of fixed ideas either in the physical or the social sciences. The abstractions which were valid as effective means of description of either social or physical phenomena must be changed. Absolute time and absolute space had to be replaced by relative time and space. Liberty and equality were originally concepts abstracted by Locke and Rousseau from a social order characterized by small peasants and proprietor. When we try to apply these abstractions to an industrial order they cannot be made to fit without modification.

As modern physics gave up absolute time and space and replaced Newtonian mechanics by relativistic mechanics, we must be prepared to hear less of absolute justice enthroned on high and the eternal and inalienable rights of man. Justice is an abstraction from social phenomena and there is nothing absolute about it. We can only have relative justice which is an abstraction from social phenomena to describe a social world out of social equilibrium and trying to regain it. It is more like saying the entropy of the system is a maximum. When social equilibrium has been reached, social justice or the social entropy of the system is a maximum.

Human rights are neither eternal nor inalienable. Just as the law of gravitation is a relation abstracted from physical phenomena so these eternal and inalienable rights are relations abstracted from social phenomena to describe conditions which should obtain in the normal state. The eternal and inalienable rights of man are no more than a description of the relations of man to man in a changing world. Any attempt to formulate them as a permanent framework must fail just as the attempt to force thinking about the physical world into the Aristotelian pattern failed. The most we can do is to discover the rules according to which social groups function and order our behavior accordingly If the phrase in the Constitution "to promote the general welfare and insure the blessings of liberty to ourselves and our posterity" is reared against the background of the present social order as we would reread the law of gravitation in light of our present physical knowledge, we wonder whether we are as ready to accept its new implications as we are ready to accept the new implications of the law of gravitation. When the law of gravitation requires that we admit a new planet like Neptune or Pluto into the solar system it is done not only without hesitation but with a good deal of satisfaction, but when we have passed from an agricultural to an industrial order and find that an attempt to insure domestic tranquillity or promote the general welfare requires that the government insure a reasonable opportunity for every man to work at a minimum wage, we think we are on the eve of a revolution in social thinking. We tardily recognize the ability of our forefathers to make universal and penetrating generalizations which are valid for all time. If Lincoln can say with general approval "A nation cannot long survive half slave and half free," we might admit that the framers of the Constitution could see that a nation could not long survive half employed and half unemployed.

Now modern theoretical physics clearly teaches that physical theory of itself has little power. It becomes powerful only when it is integrated into some system of data experimentally determined, some system of engineering needs or human wants. It is then and only then it begins to really function. If it is conceived as something complete within itself, it is essentially a brilliant but futile intellectual adventure. If there were a divorce between theory and practice in the physical science, progress would be an impossibility This only means, as Dewey points out, that intelligence in itself has no power. It is intelligence integrated into some form of human needs and demands that makes it effective. It has been one of the major errors of much of our social, cultural, and educational thinking that we have thought of education, intelligence, and culture as set apart from action as entities existing in a vacuum, as reserves against the day of decisive action. We know nothing of such segregation and such differentiation between theory and practice. We do not call one subject cultural and the other non-cultural any more than we would differentiate between one part of the body, the heart and the brain. It is much safer to keep them together and functioning as part of a unity. If the relation of the physical sciences to the engineering sciences is to teach any thing to the social sciences at this point, it must be this, using the words of Dewey. "There must be a change in the prevailing conception of social knowledge and an abandonment of the idea that knowledge comes first and action later. They must be intimately associated both in the process of acquiring them and in the process of making them function. The crucial problem is how intelligence may gain necessary power through incorporation with wants and interests that we are already operating." That is precisely how physical knowledge and engineering applications have acquired their power and this is the only method by which traditionalism based on self-interest can be eliminated from our social and economic life.

It is our opinion that the thinking characteristic of modern physics gives a firm foundation on which to base our outlook on nature and that its methods have much of meaning in them for the less exact fields of knowledge. If the biological and social sciences can be as successful in interpreting and correlating human experiences and behavior as the physical sciences have been in interpreting physical phenomena we may yet build an intellectual habitation which takes account of the fact that we are human beings living in a physical world. According to the physicists here "lies the path of advance to a clear purposed goal but it leads up a long steep journey." Its appeal lies in its certainty, and its challenge to the best collective and cooperative thinking which can be achieved through the progressive development of the human mind.